

WHAT FERRIC OXIDE/OXYHYDROXIDE PHASES ARE PRESENT ON MARS?

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INTRODUCTION

The weathering history of Mars can be deduced largely from the mineralogy and distribution of ferric oxide/oxyhydroxide phases. As discussed below, some insights can be gained through spectrophotometric remote sensing, but absolute determinations must depend on direct laboratory analysis of returned martian samples.

PUTATIVE FERRIC OXIDE/OXYHYDROXIDE PHASES

Spectral features generally attributed to ferric iron in the remotely-sensed spectral data of Mars are a weak absorption edge extending from ~400 nm to a relative reflectivity maximum at ~750 nm, inflections within the edge at ~520 and 630 nm, and a shallow band minimum near 870 nm [e.g., 1]. Certain poorly crystalline materials formed in the terrestrial weathering environment have similar spectral characteristics, implying to some [e.g., 2, 3] that the dominant ferric-containing phases on Mars are also poorly crystalline. The implication is that specific mineralogical assignments are not possible, although [4] has shown that oxide/oxyhydroxide as opposed to silicate phases are probably involved for some of the terrestrial analogue samples. The positions of the ~520, 630, 750, and 870 nm features in the martian spectra correspond to spectral features in powders of crystalline hematite ($\alpha\text{-Fe}_2\text{O}_3$) [e.g., 5], but the phase is not considered to be present by [2, 3]. Apparently, this is because of significantly reduced spectral contrast for the martian spectral features as compared to those for pure hematite powders and because hematite was not found in the XRD data of the spectral analogue samples.

Other ferric oxides/oxyhydroxides have been proposed as mineralogies for the martian surface on the basis of the Viking magnetic properties experiment. According to [6, 7], the results indicate that the surface material contains a highly magnetic component. Because it is strongly magnetic, [6, 7, 8, 9] argue that maghemite ($\gamma\text{-Fe}_2\text{O}_3$) is this component. [10] suggested $\delta\text{-Fe}_2\text{O}_3$, but this idea is discounted by [9] because the phase is apparently not naturally occurring on Earth and because it is not stable under present martian conditions. However, the stability argument can also be made against the presence of maghemite as hematite is presently the stable phase under present martian conditions [e.g., 11]. [9] do acknowledge that superparamagnetic hematite (sp-Hm) is a possibility, but they consider it unlikely because in their judgment the very small particle diameter range implied by sp-Hm (less than ~20 nm) is too restrictive.

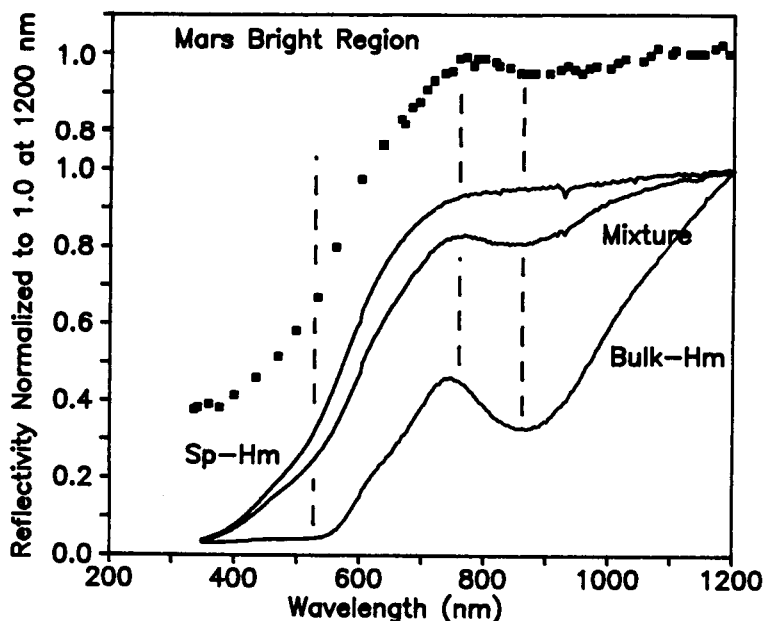
In a recent study, [12] have shown that hematite particles imbedded in a matrix material and present in a size range including bulk-Hm (larger than ~20 nm) and sp-Hm can account for the spectral and magnetic properties of the martian surface. As shown in Figure 1, a mixture of a sample of silica gel containing sp-Hm and one containing bulk-Hm produces a sample whose spectral features are like those observed for Mars in that the position of the bulk-Hm spectral features are present but with reduced spectral contrast. Thus, because of its diagnostic features, the spectral evidence for the presence of bulk-Hm on Mars is particularly compelling. Bulk-Hm is not sufficiently magnetic ($J_s \sim 0.4$ emu/g [e.g., 5]), but sp-Hm is sufficiently magnetic ($J_s \sim 5(2)$ emu/g [12]), to account for the results of the Viking magnetic properties experiment. The assertion of [9] that the size range for sp-Hm is too restrictive to be important in geologic processes is contrary to terrestrial experience. Sp-Hm and other superparamagnetic ferric oxide/oxyhydroxide

phases are commonly observed and, in some cases, are the dominant ferric-containing phase in oxidizing terrestrial environments [e.g., 13, 14].

GROUND TRUTH

Although the presence of hematite on Mars is definitely indicated, its abundance is not known and the presence of other ferric oxide/oxyhydroxide phases cannot be excluded with presently available data. Samples of the martian surface would permit definitive determination of the nature of ferric oxide/oxyhydroxide phases and their relative concentrations. This is the case provided that the samples are properly selected on Mars, properly stored during the return trip, and properly handled and analyzed in the laboratory. Core samples are probably the best sampling strategy because stratigraphy is preserved. A soil core provides a sequence of soils with different surface exposure ages; the span of the exposure ages depends on the mixing rates on Mars. It is possible that the nature of the ferric oxide/oxyhydroxide phases change with depth in response, for example, to external energy (e.g., UV radiation, particulate radiation), to aging, or to thermal gradients. A rock core would establish the extent to which oxidation is a surface or bulk phenomenon for surface rocks.

The ferric oxide/oxyhydroxide phases on Mars are likely a product of martian weathering processes. To prevent degradation of the samples (especially soils) on the return trip due to "weathering" in the sample container, the samples must be kept as cold as possible. As a minimum requirement, the samples should be kept at or below their collection temperature. Sample containers with iron-bearing walls should be avoided because of potential decomposition of the walls to ferric oxide/oxyhydroxide phases; a teflon container is suitable.



References: [1] Singer et al., *JGR* **84**, 8415, 1979; [2] Sherman et al., *JGR* **87**, 10169, 1982; [3] Singer, *JGR* **87**, 10159, 1982; [4] Sherman and Singer, *LPS IV*, 694, 1983; [5] Morris et al., *JGR* **90**, 3126, 1985; [6] Hargraves et al., *JGR* **82**, 4547, 1977; [7] Hargraves et al., *JGR* **84**, 8379, 1979; [8] Moskowitz and Hargraves, *JGR* **87**, 10115, 1982; [9] Posey-Dowdy et al., *Icarus* **66**, 105, 1986; [10] Burns, *Nature* **285**, 467, 1980; [11] Gooding, *Icarus* **33**, 483, 1978; [12] Morris et al., to be submitted, 1987; [13] Govaert et al., *J de Phys* **37**, 291, 1976; [14] Helgason et al., *J de Phys* **37**, 829, 1976.

Figure 1. Normalized reflectivity spectra for average Mars bright region [from 1], sp-Hm and bulk-Hm particles supported on silica gel, and a mixture of the sp-Hm and bulk-Hm (2.8 wt. %) samples.